BRETT L. WALKER

Sanemori's Revenge: Insects, Eco-System Accidents, and Policy Decisions in Japan's Environmental History

Normally we do not think of living organisms as machines or as relays in complex, tightly coupled technological systems. Nonetheless, in recent years this is precisely the manner in which many environmental historians have come to approach the study of certain organisms and their natural or anthropogenic environments.[1] Over the millennia and across the globe, humans have so manipulated certain organisms that they have come to exist solely as parts of technological systems or industrialized chains of production and consumption. Technological artifacts are, of course, only nature refashioned: nonetheless, modern industrialized societies tend to view themselves as gradually distancing themselves from, replacing, or, in some instances, even killing nature with their advanced technologies and gadgetries, when actually they are only refashioning their inseparable relationship to it.[2]

For the purposes of this article, two assumptions are critical to seeing organisms as technologies or as parts of technological systems. The first is that humans are capable of shaping the evolution of other creatures on this planet—in some instances our species has even caused the creation of new species, or "speciation"[3]—and that meaningful evolution can occur over the course of years and not only eons. That is, as historian Edmund Russell, a major proponent of "evolutionary history," has argued, "Organisms have changed in historical time" due to intentional and unintentional human meddling with three keystone Darwinian factors: variation, inheritance, and selection. Russell continues that investigating the manner in which human histories have shaped the evolution of other

THE JOURNAL OF POLICY HISTORY, Vol. 19, No. 1, 2007.

organisms allows us to "historicize organisms themselves," which carves out a new place for historians in generating knowledge about the current state of evolution and the natural world.[4] Historicizing organisms means that historians can trace the manner in which policy decisions, whether by silkworm cultivators, pesticide producers, or government extension agencies, have influenced the evolution of certain organisms.

The second assumption is this: if humans manipulate the evolution of certain organisms, then this manipulation, whether intentional or unintentional, resembles the manipulation of metals and electronic circuitries in machines or other conventional technologies or technological systems. Russell helps us navigate this tricky theoretical terrain as well. Strictly speaking, he explains, organisms are not conventional machines but rather are "biological artifacts shaped by humans to serve human ends." This represents a merger of technology and nature, not a separation or an instance of one killing the other. Take agriculture. As Russell explains, "No one has yet figured out how to transform sunlight, carbon dioxide, and a few nutrients into grain—except by subcontracting the job to plants. The same goes for meat production and animals."

Needless to say, industrialization is an important part of this process. As Russell points out, in the case of industrialized agriculture, "Biological development was roughly as important as mechanical innovation in boosting productivity." For farmers, that is, new hybrid grains and improved chicken breeds prove just as important in boosting production as do new threshers, combines, and mechanical feather removers. Today, farms resemble factories, and consumers, when perusing supermarket aisles, shop for carefully disassembled "legs and thighs" for their specific caloric demands.[5] More still, when we adopt "evolutionary history" as our analytical starting point, it allows us to think more co-evolutionarily as well.[6] We begin to see "not just how humans shape organisms, but how organisms shape humans."[7] Apparently, modern people, too, are products of their interaction with other organisms and, therefore, of their own co-evolutionary history.

Insects prove to be wonderful examples of organisms evolving as a result of human activities: insects such as bees and silkworms serve as biotechnologies; others develop hereditary resistances to certain pesticides. In other words, insects serve as technologies, but they also serve as targets of technologies, which causes them to evolve through developing resistances. Flying scale insects, nematode worms, and some ticks have reportedly developed resistances to such powerful toxins as buquinolate, thiabendazole, and HCH/dieldrin in only a matter of a few generations because their lifecycles are relatively short. Policy decisions play the following role: federal officials, such as those in the Agricultural Research Service (a division of the U.S. Department of Agriculture), devised strategies to use insecticides based on certain economic and political considerations related to their ties to the chemical industry and, consequently, people suffered debilitating health problems from toxic drift caused by overspraying.[8] Surely, one of the best examples of derelict public policy decisions related to insecticide use is the "fire ant wars," campaigns waged against an insect that, most serious entomologists agreed, posed little economic threat to agriculture, but nonetheless became the target of chlorinated hydrocarbon saturations that ravaged rural ecosystems and human health in the American South.[9] However, insects also developed hereditary resistances as a result of bad science and poor policy decisions. In Africa, some mosquitoes evolved in a manner that allowed them to avoid DDT sprayed in village huts; other mosquitoes, such as the tenacious *Culex pipiens,* can withstand normally lethal doses of organophosphate insecticides because it actually digests the poison.[10] In each instance, policy decisions, whether in the form of agricultural policies, public health strategies, or experimentation by pesticide producers, shaped the evolution of insects or caused human health problems as a result of ecosystem degradation.

That is to say, not just insects, but the rice paddies and other agricultural landscapes they inhabit need to be seen as technological "ecosystems." Modern rice paddies are not disorganized, unstructured landscapes, but rather are carefully parceled, highly organized segments of land, arranged in a systematic manner to increase yields and ease production. Simply, the modern farm is a factory: a complex ecological system or artificial ecosystem.[11] When sprayed, insecticides become part of insect bodies and alter their evolution through inducing resistances; but even more important, these toxins become a part of the rural ecosystems that insects inhabit, leading to systemic "normal accidents," as Charles Perrow has called them, that result from the complex, tightly coupled nature of modern agriculture. The "eco-system accident," explains Perrow, is the "interaction of systems that were thought to be independent but are not because of the larger ecology." One example of an unforeseen consequence of spraying insecticides on paddies is the biomagnification of toxins in the living tissue of organisms.[12] Perrow writes, "Eco-system accidents illustrate the tight coupling between human-made systems and natural systems. There are few or no deliberate buffers inserted between the two systems because the designers never expected them to be connected."[13]

But they are seamlessly connected. When it comes to agriculture, modern people are as much a part of the tightly coupled, complex ecosystem as everything else and, hence, prove vulnerable to system accidents in the form of toxic pollution. That is this article's main point: many environmental problems, from poisoned landscapes to disfigured fetuses, can be seen as the products of system accidents caused by policy decisions that resonate throughout hybridized environments, but only if we trace these toxins from the government and corporate organizations that sponsor and produce them, through the social networks that disseminate them, into the ecosystems that disperse them, to the human and nonhuman bodies that absorb them and, ultimately, sicken and die from them.[14] Every time we put a morsel of food into our mouths, from shiny sushi rice to crispy fried chicken, we reify our organic interface with policy decisions made in corporations, agribusiness farms, and government ministries.

This article examines six case studies of how decisions made in chemical companies, government ministries, and religious organizations led to the "historical evolution" of certain organisms or to deadly "eco-system accidents," ones that ruined the health of Japanese bodies. Our first case study is an industrial organism that served Japanese fashion rather than caloric needs: silkworms, the world's only completely domesticated insect.

Silkworms

Silkworms (*Bombyx mori*) serve as organisms that humans have, over centuries, transformed into purely industrial technologies: their survival remains utterly dependent on human beings. Today, tucked away in institutions such as "stock centers" at a handful of major East Asian universities are hundreds of Mendelian mutations of the silkworm, most of them spontaneously discovered by cultivators and then preserved; other mutations scientists induced through irradiation techniques and chemical mutagenesis. Many of these mutations represent "improved strains," or silkworms that exhibit economically desirable qualities such as rapid growth rate, cocoon size, silk filament quality, and disease resistances. Silkworms from southwestern China, for example, prove desirable because of their hereditary resistance to toxic fluoride levels in mulberry leaves, an environmental condition caused by the brick industry in that region. In effect, this is historical evolution in action: the brick industry produced environmental toxins that, over historical time, induced selection among silkworms, leading to evolutionary mutations among the organisms. This beneficial "gene," in turn, has been isolated and preserved by certain institutions for future breeding purposes.[15]

In the case of Japan, stylistic idiosyncrasies, ones that have evolved since Heian-period (794–1185) female courtiers wore some eighty pounds of silk clothing carefully chosen to match learned cultural sensibilities, influenced the evolution of silkworms as well, because only certain bugs produced the desirable high-quality filament.[16] Today, functional genomics has allowed institutions to engineer silkworms that produce such specialized silks, as well as recombinant proteins made in the silk glands with beneficial pharmacological qualities. Indeed, within certain institutions, Japanese scientists have accumulated entire databases that hold silkworm DNA, from where they distribute clones internationally for commercial and scientific use.[17] Because no wild silkworms exist (their closest relative is *Bombyx mandarina*), they represent one of the oldest examples of historical evolution and organisms being used as industrial technologies. Certainly in Japan, silkworms have depended on their doting human providers, mostly women, for millennia.

Silkworms have long been in Japan, as evidenced by eighth-century creation mythologies. During one divine encounter narrated in the *Kojiki* (Record of Ancient Matters; 712), the intrepid, but also quite hungry, deity Susano'o kills the food deity, Ogetsuhime, because he thought she sought to pollute him by pulling various foodstuffs out of her nose, mouth, and anus. Evidencing the importance of silkworms in Japan's ancient mythologies and economies, from Ogetsuhime's divine corpse grew the vital grains—the foodstuffs on which Japanese have endured for centuries—and also silkworms.[18] The myth explains, "In the corpse of the slain deity there grew [various] things: in her head there grew silkworms; in her two eyes there grew rice seeds; in her two ears there grew millet; in her nose there grew red beans; in her genitals there grew wheat; and in her rectum there grew soy beans."[19] In others words, Japanese wove silkworm cultivation into the deepest fibers of their cultural fabric; and the caterpillar's incremental domestication paralleled the domestication of Japan's earliest food crops.

Preindustrial rural households tended their silkworm nurseries with the same sort of care that they did their rice, millet, bean, wheat, and soybean fields. For the past two centuries, when rural households purchased silkworm eggs, often they exchanged no money and the agent simply deducted his proceeds when the worms had spun their precious silk cocoons. Until they hatched, often as many as twenty thousand of these eggs laid spread out on wooden trays; once hatched, farmers carefully brushed the squirming larvae onto rearing trays using a soft feather so as to not crush their tiny bodies. Farmers covered the rearing trays in wet rice husks to provide the necessary humidity and then spread out a layer of chopped white mulberry (*Morus alba*) leaves for the silkworms to munch on. Often families sacrificed their sleeping space to provide comfortable accommodations for these bugs.

For about three days the larvae devoured carefully cut mulberry leaves; on the fourth day they hibernated. But then they shed and were reborn, with gauzy skin and bright stripes down their bodies. Such metamorphic qualities—their biological ability to change into completely different creatures—did not go unnoticed by the Japanese and insects became potent symbols of Buddhist notions of transmigration: when the soul, in the endless cycle of birth and rebirth, travels to the next life after this one. Eighth-century mythmakers marveled in the *Kojiki* at the metamorphic quality of silkworms as well. "Among the insects raised by Nurinomi," a fourth-century migrant to Japan, "there is a strange variety of insect that changes three ways; first it becomes a crawling worm, then again it becomes a cocoon, then once again it becomes a flying bird."[20] As with the East Asian writing system (called *kanji* in Japanese) and other technologies and institutions, sericulture was perfected by migrants who came to Japan on well-trodden migration circuits between the fourth and eighth centuries, mainly from the Korean peninsula.

In nurseries, by the fifth or sixth day, silkworms grew to the point where cultivators needed to carefully spread them out on even more trays, with an ever-ready supply of fresh mulberry leaves. Silkworms grew at a tremendous rate and, by the time they started spinning their silk, they weighed some ten thousand times their weight as larvae. The silkworms ate and molted and ate and molted some four times in all, until, after their final metamorphosis, they prepared to spin their cocoons by eating steadily for six days straight. By this time, the silkworms measured about one to two inches in length, walked dexterously for having eight sets of legs: three sets of jointed legs, with a sole claw at the tip, and five sets of fleshy leglike protrusions with hooks for climbing and clinging. They also sported a lavishly decorative short "anal horn" on their backs. When in the larval stage, silkworms preferred the delicate shoots from the tops of the mulberry, but later, when adults, they ate everything even remotely mulberry: the some twenty thousand larvae cultivated by one rural household consumed a total of thirteen hundred pounds of leaves.

Farmers set aside thousands of acres for growing mulberry to feed hungry caterpillars, often when there was barely enough land to grow grain to feed the people of their villages. In the eighteenth century, some of the best agricultural lands around Japan's major cities—in the Kanto Plain around Tokyo and the Kinai and Kansai areas around Kyoto and Osaka—farmers replanted with mulberry and land for raising vital human food crops, such as soybean, sprang up in more distant areas in the northeast and elsewhere. The market demand for foodstuffs to feed hungry urban populations forced a monoculture regimen on distant areas such as Hachinohe in the far northeast, setting the region up for devastating famine when soybean crops failed because of weather and, in one bizarre instance, exploding populations of hungry wild boar.[21] All this so that mulberry trees could be cultivated to feed more and more hungry bugs. This is the essence of co-evolution: humans sacrificing their own precious farming lands to feed hungry bugs on whom they depend economically. Indeed, with their tiny heads, silkworms must have nodded with satisfaction as Japanese farmers eliminated rice and soybean croplands to make room for more mulberries and refashioned lending patterns, risked awful debt, kept children at home, and sacrificed their already squalid living space just to nurture them.

When silkworms began spinning, families designed special frames for them to hang from. Timing was critical at this stage, because the worms had to be ready to spin their cocoon; they simply soiled the cocoons of others if they were not and this ruined the quality of the silk. Over the next several days, the family eagerly watched as the worms went to work on their beautiful translucent cocoons made from thread excreted from special glands: a piece of evolutionary hardware that has allowed these creatures to be treated with such care. Once they completed the cocoon, they molted one final time, and eager farmers raced the cocoons to silk agents to collect their earnings. Farmers boiled poor-quality cocoons to make silk thread for their own clothing; some ate the plump, protein-rich insects or fed them to fish in communally tended ponds. Little was left to waste in preindustrial Japan. Later, in the period just before the Pacific War (1937–45), silk agents paid between one and two hundred yen for these cocoons. (One cocoon could produce more than fifteen hundred feet of valuable silk thread.) Obviously, when entire colonies of silkworms perished, it financially wiped out these already deeply impoverished rural households, who famously produced no less than 70 percent of Meiji tax revenues through absolutely crushing land taxes.[22] Rural families shouldered financially Japan's industrialization; they did so environmentally, too.

The silkworm provides an excellent example of an industrialized organism whose life has been shaped by policy decisions made by cultivators and rural lending institutions, ones that are then transferred through economic systems, social networks, and rural ecosystems. Silkworms symbolize our intentional and unintentional meddling: creatures that evolved according to the needs of our economic, cultural, social, and ecological systems. Think of it this way: the Japanese desired certain silk fabric from certain kinds of caterpillars because of traditional cultural sensibilities; the Japanese bought silkworms in the manner they did because of the development of rural financial institutions; and the Japanese, particularly the smaller, dexterous hands of women, raised silkworms in homes because patrilocal Confucian kinship patterns had sequestered them there.[23]

Insects, Buddhism, and Japanese B Encephalitis

Our second case study examines the manner in which cultural sensibilities inherent in Buddhism and biogeographical ones inherent in Japan's nineteenth-century decision to adopt industrial agriculture led to the creation of ideal habitat for certain mosquitoes that carried neurological diseases that threatened human health. Biologically, silkworms underwent three distinct transformations on their way to their final destination of becoming a moth. For this evolutionary talent, the Japanese associated such insects as silkworms, butterflies, cicadas, and mosquitoes with metamorphic qualities likened to the cyclical nature of human existence according to Buddhist cosmologies. Insects such as silkworms and cicadas started out as eggs, they hatched and became hungry larvae, they matured to even hungrier pupa, and, in their final transcendence, they sprouted wings. For this reason, Japanese literary classics are littered with insect references, usually alluding to the sadness or the impermanence of this transient world.[24]

In the nineteenth century, Lafcadio Hearn (1850–1904), an American living in Japan, wrote lengthy meditations on insects and Buddhist notions of impermanence. Hearn lived in Japan in the metamorphic Meiji years (1868–1912), when Japan itself shed its skin, and he lamented the cruel destruction of an older Japan in favor of the new industrial order. Similar to the silkworms and cicadas he observed, Hearn too underwent a metamorphosis while living in Japan when he adopted the Japanese name Koizumi Yakumo and, in his own mind, sprouted wings and became in many respects "Japanese."[25] When writing about butterflies, Hearn retrieved ancient Japanese and Chinese myths that the souls of the deceased wandered this world in the form of butterflies, sometimes eavesdropping on former lovers. According to another story, butterflies descended on the ancient capital of Kyoto by the thousands in the tenth century and, in doing so, portended the countless men to be killed and resurrected as insects during the rebellion of Taira no Masakado (d. 940).

But Hearn also tied the fate of mosquitoes to the fate of the older Japan he cherished. The mosquitoes that infested his Tokyo neighborhood and stung him originated in a deeply spiritual place, in a nearby cemetery, where, at the foot of ancient, moss-covered Buddhist tombs, worshipers placed water in *mizutame* (cisterns) so that the souls of the dead, when reborn and preparing for their otherworldly journey, could satisfy their insatiable thirst. But his neighborhood cemetery was an old one, and the standing water in the tens of thousands of cisterns and flower receptacles proved excellent breeding habitat for mosquitoes—under Meiji Japan's hygienic regimen, a health risk. The mosquitoes that so pestered Hearn and other Tokyoites rose "by the millions from the water of the dead," he wrote. He speculated, referring to Buddhism's six realms of existence, that "some of them may be reincarnations of those very dead, condemned by the error of former lives" to wander the earth as blood-suckers. He marveled that "some wicked human soul had been compressed into that wailing speck of a body."[26]

Here Buddhist orthodoxies intersected with ecological systems, and the cisterns and vessels left at the cemetery provided water for transmigrating souls as well as prime breeding habitat for mosquitoes: religious practices and cultural sensibilities interfaced with ecological ones and caused an urban health crisis. That is, had it not been for the religious demand for cisterns, the cascading and unforeseen "ecosystem accidents" that resulted from these cemeteries would not have occurred. Indeed, these swarms of Japanese insects represented a serious threat in the eyes of a Meiji government increasingly concerned with national discipline through the health and hygiene of Japan's citizenry. Some of the mosquitoes (*Culex tritaeniorhynchus*) born in these Buddhist cisterns carried the "arbovirus" (arthropod-borne virus) that causes Japanese B encephalitis. Normally, these mosquitoes live and breed in the marshy paddy lands of rural Japan, but standing water in cities attracts them as well. One reason the mosquito-borne disease thrived in rural areas, but later came to the outskirts of cities, was because this peculiar virus spends part of its lifecycle in the bodies of pigs, who serve as an "amplifying host." With the advent of modern agriculture (there had been little animal husbandry in preindustrial Japan), vast numbers of pigs came to live near human populations.[27] Between 1926 and 1938, about the same time that several high-profile Japanese B encephalitis outbreaks occurred, Japan witnessed nearly a 100 percent increase in its pig population, from 504,758 to 997,980. Although small rural cultivators raised most of these pigs, some large-scale producers, according to later U.S. occupation documents, were "located on the outskirts of the large cities," where the animals had easy access to garbage for feed.[28] Obviously, the decision to place large concentrations of pigs near cities (and their accompanying cemeteries with mosquitoes and, nearby, human populations) set Japan up for "ecosystem accidents" in the form of Japanese B encephalitis epidemics.

Mosquitoes sucked the blood of these pigs and transported the blood-borne, amplified virus to nearby human hosts. Most people do not develop severe symptoms of Japanese B encephalitis, but when they do, the disease can be devastating, causing death or brain damage and paralysis. In 1924, some 6,000 reported cases of encephalitis left 3,800 people dead in Tokyo alone; that same year, the disease also occurred in Kagawa District of Kyushu, where 60 percent of those who contracted the affliction—some 3,500 souls—died of fever and brain swelling. Japanese B encephalitis was also one of a host of afflictions that plagued Japan immediately after the surrender to the Allies in 1945.[29]

A ghoulish aside to our story of encephalitis is Ishii Shiro (1892–1959), the eccentric young Japanese biologist who invented the filtration device that proved instrumental in isolating and identifying the virus. His career later proved a sinister one, as he applied his scientific expertise in water impurities, filtration, arboviruses, and insects to develop Japan's biological weapons program in China.[30] Although outside the scope of this article, Ishii oversaw a biological weapons program in China during the Pacific War, which, among other horrific enterprises, raised bubonic-plague-carrying fleas in nurseries (much in the manner that villagers had raised silkworms), packed them in bombs in swabs of cotton, and then released them over Chinese cities such as Ningbo (27 October 1940) and Changde (11 April 1942).[31] The Japanese killed thousands of Chinese civilians with this military biotechnology. This policy linkage between killing anthropoids and arthropods is not surprising, however. The same European and American companies that developed chemicals and aerial dispersal technologies to kill bugs easily transferred them to human battlefields and visa versa during times of war.[32]

To summarize, the manner in which Japanese viewed the transmigration of the soul, modern agricultural, and their "vermin" Chinese neighbors in times of war, led to epidemiological outbursts of Japanese B encephalitis and epidemics of bubonic plague. Policy decisions underwritten by religion, agriculture, and ethno-nationalism interfaced to threaten the health of human bodies at home and abroad. But explanations of the transmigration of the soul also shaped how rural Japanese explained the outbreak of famine.[33] One of the best-known historical examples of insects causing severe crop damage and famine in Japan—insects harming Japan's earliest hybrid agricultural systems—is the Kyoho famine. In the following examination, Buddhist attitudes toward the transmigration of the soul shaped Japan's initial foray into "economic entomology," because tackling the threat caused by agricultural pests meant placating the former humans whose souls inhabit the tiny, buzzing bodies of insects such as plant hoppers and locusts.

Early Modern Japanese Famines and Insecticides

The Kyoho famine of 1732—one of Japan's three "great famines" of the early modern period (1600–1868)—was partially caused by insects and, after its outbreak, ravaged central and western Japan, particularly the islands of Kyushu and Shikoku. *Unka,* or plant hoppers of various subspecies, represented the principal troublemakers during the 1732 famine: farmers reported, in the beginning of the sixth month of the lunar calendar, massive emergences of one species of rice plant hoppers (*Sogatella furcifera*) and, about two weeks later, a second wave of a different species (*Nilaparvata lugens*). To this day, these delphacid insects represent serious threats to rice crops throughout Asia, though in temperate climates, such as those in Korea and Japan, the hoppers do not survive the winter. They therefore travel to these countries on seasonal winds from southeastern China, coordinating their arrival with the transplanting of lush, green rice crops in spring and early summer.[34] In 1732, hoppers coordinated their arrival perfectly, and Kyushu farmers reported widespread crop damage as a result of these two waves of insect invaders.

In other locations, such as in Komatsu domain, in Iyo province on Shikoku Island, farmers reported insect damage in the form of *mushigui,* a reference to hoppers infesting rice stalks and sucking these plants dry of their life-giving juices until they simply withered, turned brown, and died. So many hoppers swam on the surface of the paddies that the water turned "the color of soy sauce." During the day, the hoppers stayed on the rice stalks, contently sucking the juices; at night, however, when farmers inspected the crops with pine torches, they saw that the insects had moved to the heads of the plants, where they ate the precious grain itself. Despite prayers offered at temples and shrines to disperse the insects, crops turned brown, withered, and died; farmers watched helplessly as insects less than an inch long unceremoniously consumed bushel upon bushel of the gold standard of Japan's early modern political economy.[35]

Not only cultivators in Komatsu, but those in Hiroshima domain experienced hopper infestations as well: they peaked around the sixteenth or seventeenth day of the seventh month of the lunar calendar. Farmers described the hoppers as having risen up from the "earth's vapors" to resemble giant plumes of noxious smoke hovering over the crops. Farmers also noticed, however, that during the first ten days of the eighth month, when temperatures dropped, the hoppers died off, because they coped poorly with Japan's temperate climate. Farmers in the five home provinces around the ancient capital of Kyoto—the Kinai region—similarly reported infestations of hoppers so large (probably a third wave of the leaf hopper *Cicadula sexnotata*) that they resembled the "golden coin beetle," a pesky insect known in the United States as the "Japanese beetle." Farmers explained that the hoppers sported an exoskeleton that resembled protective armor, that they flew, and that in one night a swarm of them ate the equivalent of literally tens of thousands of bushels of rice. In the Kinai, farmers compared the hoppers to the "golden coin beetle," but in the western provinces they referred to the pest as Sanemori. Just as Lafcadio Hearn had ruminated on the transmigratory lives of mosquitoes in a nearby cemetery, farmers in Japan's western provinces believed that the insects were actually the spirit of the vengeful general Saito Betto Sanemori (1111–83), who, in the twelfth-century, had died in the fields of Shinohara of Kaga Province at the hands of rival Tetsuka Mitsumori.[36] Farmers believed that Sanemori continued to hold a grudge against the farmers of western Japan and so he came back in the bodies of plant hoppers to ruin their rice crops: this was the principle behind their Buddhist-inspired entomology. It also shaped how early modern rural entomologists sought to eliminate the threat caused by these pests.

To frighten off the spirit of Sanemori, farmers from the western provinces fashioned scarecrows from straw, which they strategically placed along coastal shorelines or on the borders of their villages and rice paddies. When Sanemori (now better armored than in the twelfth century) ignored these straw men, farmers employed what they referred to as the "oil extermination" technique by pouring rapeseed or whale oil on the water of their paddies in order to suffocate hoppers that fell into the water. This "oil extermination" method represents one of the first uses of insecticides in Japan. Rural lore explains that resourceful farmers invented the "oil extermination" technique in Chikuzen province, on Kyushu Island, in 1670, but later improved on the technique by lighting it and burning the insects alive. A treatise on "insect control" by Okura Nagatsune (1766–1860) contains illustrations that depict farmers burning hoppers with oil and pine torches. Apparently the technique was discovered when, one night, a man named Yahiro, while lighting temple lamps, noticed that hoppers flew into the lit oil and died, and so desperate farmers replicated the technique on a larger scale. In Fukuoka domain, also in Chikuzen, farmers called the hopper infestations a "vision of Michizane's Dazaifu spirit," a reference to legendary classical scholar and statesman Sugawara no Michizane (845–903). On being exiled by political rivals to Dazaifu, capital of the western provinces (in present-day Fukuoka prefecture), Michizane died in disgrace, but, shortly after his death, his rivals in Kyoto began dying too, and so north of Kyoto a shrine was erected in honor of "Tenman Tenjin," his posthumous, deified name. His spirit remains associated with rigorous scholarship and continues to grace smart young Japanese entrance-examination-takers to this day. Farmers in Fukuoka, close to Michizane's grave, no doubt assumed that he had taken the form of plant hoppers, much as Sanemori had in Kaga province.[37]

Okura Nagatsune's "insect control" treatise, entitled *Jokoroku,* serves as a fascinating example of the methods used by rural cultivators to protect their crops and exterminate plant hoppers and locusts. He began the treatise by observing that, in times of unseasonable weather, plant hoppers and other rice-eating insects (*unka*) appear on rice crops and, after severely damaging them, famine often results. Famine, he insisted, represented the "number one affliction of the realm." In retrospect, he was probably right. He continued that "farmers must learn the methods of preventing [damage caused by] plant hoppers" if the realm-wide scourge of famine was to be eliminated. Okura's principal example of the dangers of insects and famine was the Kyoho episode; but he recalled the intense hardships of the Tenmei famine as well, specifically the unseasonable weather of 1783 and 1787, when he was a young child growing up in Hitashi in Bungo province (present-day Oita prefecture). So he knew from personal experiences the dangers of insects and famine and sought to prevent it through the use of insecticides.[38]

During the Kyoho famine, farmers tried these and other methods of insect control. Fukuoka farmers applied nearly one gallon of "fish oil" per acre to rid their paddies of the angry Michizane: Japanese refashioned fish and whales into technologies of insect eradication. The technique developed in Fukuoka quickly spread throughout the provinces of western Japan, as in Matsuyama domain, in Iyo province, farmers reportedly tried the technique in their paddies as well. But fish and whale oil proved expensive and beyond the economic means of most farmers; and the fact that the policy of domain lords, and even the Tokugawa shogun, was to order prayers at various temples, though magnanimous indeed, probably did little to stem the hopper tide. The shogun also had associated insects with disgruntled ghosts, and, in what we might see as an official

Buddhist-inspired policy response, ordered prayers at Japan's most sacred sites, including such institutions as the Ise Shrine, the Grand Shrine at Izumo, Buzen Usa, Hitachi Kashima, Katori, Iwashi Mizuhachiman-gu, the Nikko mausoleum, the Enryakuji Temple at Mount Hiei, and Gojiin. When domain lords formally reported the damage done to crops, the shogun generously reduced their *mononari,* or yearly rice tribute, and even offered loans to the most devastated areas.[39]

Sadly, the cool temperatures in the eighth month that stemmed the tied of hungry plant hoppers also successfully killed off what remained of western Japan's rice crops. The combined damage from insects and unseasonable weather hit Matsuyama domain particularly hard, destroying most of its harvest. There, farmers desperately experimented with whale oil to kill insects, but the technique did little good and in 1732 the lord reported that 3,489 people had died of starvation, along with 1,694 oxen and 1,403 horses.[40] The Kyoho famine became known as one of early modern Japan's "three great famines," the others being the Tenmei and the Tenpo famines.[41] What makes it important is that, in the midst of the deadly crisis, Japan's earliest economic entomologists experimented with a variety of oils and techniques to rid crops of hungry plant hoppers, experiences that rural cultivators and their children's children carried with them into the modern age of agricultural science.

To review, policy decisions made by Japanese farmers or officials in the Tokugawa shogunate designed to tackle the deadly Kyoho famine—setting up scarecrows on the coastline, conjuring spells, worshiping at temples and shrines, anthropomorphizing insects with the transmigrating spirits of past statesmen, and relying on whale oil as an insecticide—expose how Buddhist sentiments, early agrarian technologies, and the Tokugawa government (and its reliance on the *kokudaka* system) directly shaped famine, the pathology of disease, and the nature of premature mortality in Japan. Here cosmological and agronomic systems intersected seamlessly with entomological ones: an example of the manner in which human-designed religious orthodoxies, government decisions, and technologies manifest themselves in the natural world.

Meiji Insecticides

Plant hoppers, locust, scale insects, and other insect pests proved no less dangerous under the Meiji government (1868–1912) than they had under the Tokugawa shoguns. But Meiji modernizers felt more pressure than ever to increase agricultural yields on croplands because, with industrialization, more people transferred from rural areas to newly constructed urban factories to work as laborers. So, in essence, Japan's working lands needed to feed and thereby fuel a growing industrial population with fewer people actually cultivating them.[42] For this reason, fertilizers and insecticides proved invaluable to Japan's modernization designs: in effect, farmers boosted yields with chemical fertilizers and, through increased use of insecticides, hoped to share fewer of their painstakingly produced calories with always-hungry six-legged competitors.

Early modern farmers processed whale blubber and rapeseeds and turned them into agents of insect control; Meiji Japanese sought other remedies to eradicate pests, remedies more chemical in nature. They deployed chemicals because the manner in which Japanese viewed agriculture and entomology changed: in the modern scientific order, casting spells, offering official prayers at shrines and temples, and setting up scarecrows smacked of a superstitious past. Chemicals, by contrast, represented the promise of Euro-American science, a new form of "magic," much as Buddhism has been centuries earlier, one rooted in economic entomology and advanced chemistry, not theories regarding the transmigration of Sanemori's bitter soul.

What set the Meiji approach apart was less a reliance on rural folk remedies and more an obsession with European and American science: the obsession with science translated into an early experimentation with simple chemical means of killing insects in the context of a more industrialized agricultural regimen.[43] And nowhere in nineteenth-century Japan was modern, industrialized agriculture more coveted than on the newly acquired island of Hokkaido, where the Kaitakushi (Hokkaido Development Agency) hired foreign experts from the United States and elsewhere to assist in the creation of modern agriculture on that island.[44] And, typical of nineteenth-century agricultural modernization in Japan, the United States, with its network of land-grant colleges, extension agencies, experiment stations, and state and federal development offices, provided Meiji policymakers with model institutions.

As early as the 1840s, U.S. economic entomologists had begun pushing for greater relevancy in the agricultural sciences. That is, they no longer wanted to be seen as quirky men with thick glasses, whose homes were cluttered with case upon case of needle-impaled insect specimens; they wanted to contribute to practical science, and they did so by conjuring up a war against insects in America's working lands. But there was a degree of reality to the war against insects: increasing urbanization had demanded more mono-crop agriculture to feed people, which made crops more susceptible to insect damage. In 1854, the U.S. government hired a lone entomologist to travel the country cataloging and collecting information on noxious insects; by 1868, the same year as the Meiji Restoration, some states followed suite and hired entomologists as well. At this early juncture, among the insecticides sprayed on crops throughout the United States in the nineteenth century was "Buhach" (the American proprietary name for pyrethrum powder), "Paris green" (a copper acetoarsenate), "London purple" (basically calcium arsenate), "lead arsenate," and "Bordeaux mixture" (to be discussed below). Signs of trouble related to the use of such insecticides appeared early on, however. In 1891, for example, a public-health scare related to poisoned grapes and "Bordeaux mixture" rocked New York City; later, public health officials debated the degree to which arsenic, which cultivators sprayed liberally on fruit crops, caused chronic health problems among consumers. That is, the use of arsenic as an insecticide forced the medical community to grapple with the long-term chronic health consequences of arsenic poisoning.[45]

Drawing on the U.S. experience, Hokkaido's working lands became nothing less than laboratories—literally, experiment stations—where the Kaitakushi tested newly imported agriculture technologies, including chemical insecticides. One of these technologies was an inorganic carbon-sulfur compound used to combat scale insects in orchards as well as rusting disease on wheat crops in 1874. The compound "lime sulfur," as farmers commonly called it, proved effective against wheat crop and apple orchard diseases, such as fungal head blight (*Gibberella zeae*), wheat leaf rust (*Puccinia triticina*), and powdery mildew (*Podosphaera leucotricha*), as well as insects such as red mites (*Metatetranychus citri*) and arrowhead scales (*Unaspis yanonensis*). In 1881, moreover, Meiji modernizers began importing "pyrethrum powder" from England (made from chrysanthemums); four years later, they imported seeds for insect-repelling chrysanthemums from the United States and, once in Japan, farmers cultivated the plants throughout the country. The plants proved so successful that by 1898, Japan, with the support of the Meiji government, became an exporter of dried chrysanthemum flowers to the United States. Simultaneously, Japanese scientists experimented with a variety of chrysanthemum-based chemical insecticides, including mosquito incense. In 1901, Japanese agronomists developed a "chrysanthemum-petroleum emulsion" that farmers used as an insecticide throughout the country. More important, Japanese scientists participated in the development of "pyrethroid," a synthetic version of the naturally occurring "pyrethrum." This chemical proved to be one of the four big insecticides of its day.[46]

In 1897, Japanese agricultural organizations, such as the Japanese Association for the Prevention of Plant Disease (Nihon Shokubutsu Boeki Kyokai) and the Japanese Association for Research into Regulated Chemicals (Nihon Shokubutsu Chosetsuzai Kenkyu Kyokai), also experimented with "Bordeaux mixture" at experiment grape vineyards in Japan. "Bordeaux mixture," developed by Pierre-Marie-Alexis Millardet (1838–1902) in the 1860s, is a fungicide and bactericide made from copper sulfate and hydrated lime. Other simple chemical compound insecticides and bactericides experimented with included hydrocyanic gas fumigants, Horumarin soil disinfectants, and arsenic acid; naturally occurring insecticides included sulfuric acid, nicotine, and Rotenone.

At experiment stations and elsewhere, Meiji policymakers tested a variety of new chemical insecticides, and this project was closely tied to industrialization. Simply, workers and soldiers needed calories. This interest in insecticides set the Meiji government apart from its early modern predecessor. Through such institutional appendages as the Kaitakushi and agricultural experiment stations situated throughout the country, not to mention a variety of agricultural research organizations, Meiji policymakers directly initiated elaborate national modernization projects and, in the realm of agriculture, established a precedent followed for decades for state-supported insecticide production and deployment. That is, now the modern state, which projected its will through extension agencies and networks and whose representatives rose to power through distinctly Japanese political practices, began altering the natural world. In the modern period, an institutional triad shaped the nature of insecticide production and application: the government, large chemical corporations, and cultivators. Unlike the Tokugawa shogunate, which displayed its support for insect eradication through spells cast at sacred sites, the Meiji government offered resources to a wholly new belief system—science—lending economic support and bringing the technologies and human resources to Japan required for the development of a domestic chemical industry. The case of chrysanthemum-based chemicals is important. In just under two decades, Japan transformed from an importer of "chrysanthemum powder" from England to an exporter of "dried chrysanthemum flowers" to the United States. The same scenario holds true for the production of "parathion" in the 1950s. At first, the chemical giant Sumitomo Chemical imported the highly toxic insecticide from the United States and Germany, but after some prodding by Japanese policymakers concerned with skyrocketing trade deficits after the Allied Occupation, the company began domestic production in earnest by mid-decade.

Not only did nineteenth-century Japan trade ideas, policies, and institutions with Western countries in the name of modernization, it also traded manufactured items such as silk fabric and botanical rarities such as azaleas, all in the name of global commerce. And similar to the manner in which Meiji oligarchs winced when they learned that the democratic writings of Thomas Jefferson (1743–1826) and Jean-Jacques Rousseau (1712–78) had crept into Japan along with Prussian ruminations on centralized monarchical power, so did American entomologists when they learned that hungry beetles had hitched rides on azaleas when Japan exported them to the United States.[47] The saga of the Japanese beetle occurred as a result of Japan's participation in global commerce, but the response to the Japanese beetle crisis, as portrayed in our next case study, reveals a great deal about agricultural policymaking and cultural attitudes toward insects in Japan and the changing nature of economic entomology in the United States.

Japanese Invaders

In the early modern period, farmers in western Japan imagined plant hoppers as the disgruntled spirits of famous medieval warriors and classical statesmen, even though they traveled to Japan on winds that originated in southeastern China. Early twentieth-century ecologists in the United States, operating under a different logic, referred to such foreign insects as "invader species" and took an altogether different approach to understanding and controlling them. The Japanese beetle (*Popillia japonica*), known as the "golden coin insect" in western Japan, invaded the United States in the summer of 1916, when the hungry chafers established a beachhead at a nursery in Riverton, New Jersey. When compared to the "helmeted beetles" (*Allomyrina dichotoma*) that children in Japan collect and raise in small plastic terrariums and whose shells resemble the ornate armor of medieval samurai warriors, the Japanese beetle is rather ordinary in everything except for its reflective golden color and voracious appetite for the same crops that humans tend to cultivate and eat. Evolution has made it an economic competitor, not an insect that contributes to human economies, such as silkworms or even bees. State and federal agencies in the United States, in policy decisions lamented in the pages of Rachel Carson's *Silent Spring,* deployed insecticides in earnest to kill beetles in mass numbers, chemicals that later became popular in Japan.

According to economic entomologists, in the first year of its invasion the beetle inhabited a modest area of about one acre; by 1941, the year

Japanese zeros bombed Pearl Harbor, beetles had made far more impressive gains than Japan's skilled pilots and inhabited some twenty thousand square miles of soil in the American homeland. East Asian farmers rarely considered the Japanese beetle a serious pest, but once the beetle arrived in New Jersey—its grubs tucked quietly in the bundled roots and soil in a shipment of azaleas—the lack of native predators or diseases meant that it quickly went to work on crops across the country, destroying everything from soybean and clover to apple and peach trees. In the early 1920s, other "Oriental" invader species followed the gains made by the Japanese beetle, including the camphor scale (*Pseudaonidia duplex*) and the Asiatic garden beetle (*Autoserica castanea*).[48] These insects, but mostly the Japanese beetle, represented a scourge on the civilized face of the planet, much as the American propaganda machine famously made out the Japanese people to be once the Pacific War got under way.

By August 1945, even though the United States had subdued, though not eradicated, "Louseous Japanicas" with incendiary bombs and atomic weapons, the Japanese beetle continued to molest crops unimpeded throughout rural America. Rachel Carson featured Japanese beetle eradication campaigns in the Midwest as among the most egregious examples of the dangers of chlorinated hydrocarbons when sprayed indiscriminately over American's pastoral landscapes. Although she did not necessarily identify the campaigns as such, often they exemplified how policy decisions made in institutions, such as in chemical corporations or local and federal government organizations, resonated throughout social networks and ecosystems and, ultimately, harmed human and nonhuman bodies. In 1959, for example, specially equipped airplanes doused about twenty-seven thousand acres in southeastern Michigan with aldrin, a highly toxic and relatively inexpensive insecticide, reportedly to manage the beetle infestation in that area. Despite that fact that some local entomologists questioned the necessity of the program, the aldrin dusting continued apace and, although the beetles survived the bombing, such birds as the American robin did not. Dead songbirds lay strewn around people's lawns. Similarly, between 1954 and 1961, Illinois dusted some 131,000 acres with dieldrin, which, in laboratory tests, proved some fifty times more toxic than the infamous DDT.[49] Here, songbirds and household pets began dying throughout the sprayed areas as well.

What made such campaigns of "annihilation" and "extermination" so tragic is that the Japanese beetle, after about 1954, had, in most instances, ceased to be a serious agricultural pest, as populations had started to stabilize after the initial invasion, largely because of the decision to import new biotechnologies: predatory insects and bacterial "milky" disease from the beetle's native habitat. In retrospect, one can only imagine that, when those first Japanese beetles made landfall in New Jersey in the earthy roots of azaleas, they celebrated their arrival in an environment free of at least ten mortal insect enemies. In Japan, a kind of tachinid fly (*Centeter cinerea*), through its own reproductive activities, tirelessly kept "golden coin insect" numbers in check through an ecological equilibrium between the two species that is centuries old and actually quite gruesome. Indeed, the fly's unwieldy name in Japanese is Mamekoganeyadoribae, or "the fly that lives within the Japanese beetle." In their native habitat, among the favorite haunts of Japanese beetles ranks a variety of knotweed (*Polygonum reynoutria*). In this bushy, green world, tachinid flies hunt for unsuspecting (and usually love-struck) beetles on the leaf tops. So horrified of tachinid flies are Japanese beetles that if they even catch a glimpse of one they become alarmed and quickly drop from their leafy cover to the ground rather than risk confrontation with this ruthless predator. If the fly moves toward the beetle, sometimes the two engage in a gripping life-or-death struggle. Tachinid flies have compensated by normally preying on mating beetles, which usually prove too preoccupied with copulation to notice when the fly silently stalks them. There is good reason why these small flies scare Japanese beetles so much. They would you too if you lived in this microscopic world: it is all about scale.

Tachinid flies do not immediately kill and eat the beetles. Instead, after observing the mating beetles for some time, a female tachinid identifies the female beetle and, in a lightening-fast diagonal run, quickly maneuvers herself to lay several eggs on the thorax of the female beetle. In the early 1920s, U.S. researchers from the Bureau of Entomology noticed, once they arrived in Japan, that in northern parts of the country nearly all of the Japanese beetles inspected had such eggs around their thorax. Having attached her eggs to the beetle's thorax—or "provisioned her eggs"[50]—the female fly's work is basically done; but it serves as a six-day death sentence for the beetle. The larvae within the eggs develop in about two days and, rather than hatch externally, the larvae employ rasp-like teeth to bore through the shell of the egg and directly into the thorax of the beetle. Eggs mistakenly deposited on more armored and, therefore, better-protected parts of the beetle's exoskeleton often prove unable to penetrate the body cavity and quickly perish trying. Once in the thoracic cavity, the larvae molt and then move into the main body cavity, attaching themselves with a perforated hook to air sacks in order to breathe. The beetle, being eaten alive from the inside, usually buries itself in the ground. In the body cavity of the beetle and underground, the larvae then move back into the thorax, mercifully killing the beetle host in the process; later, still living inside the beetle, the larvae literally eat the entire content of the body cavity. Four days after the beetle has died and nine days after the female fly originally attached her eggs, the larvae metamorphose into a pupa and survive in the buried cavity until they emerge in the early morning hours some ten months later. Once mature, the female flies then search for another love-struck female beetle on whom to lay their eggs and procreate. The engineers at chemical giant American Cyanamid could never have even dreamt up such an effective insect-killing machine, particularly one with so little collateral damage. Because of the tachinid fly and other predatory insects, Japanese beetles never posed much of a threat to Japanese farmers, unless, of course, these farmers unwittingly used chemicals that killed tachinids, which they often did.

Starting in 1921, the team from the Bureau of Entomology (part of the U.S. Department of Agriculture) paid over two hundred Japanese children to collect parasitized specimens of the Japanese beetle to be shipped to the United States and released at ground zero in Riverton, New Jersey. The Japanese kids must have had a blast making money in their age-old hobby of netting insects. As far back as the early eleventh century, Japanese courtiers wrote nostalgically of the ringing songs of the bell cricket (*Homoeogryllus japonicus*), which they described poetically and, in typical Japanese fashion, onomatopoeically. Courtiers sometimes collected these emotionally evocative insects and then set them free in their gardens. Tachibana Narisue, in his *Kokon Chomonju* (Notable tales old and new) described children meeting in 1095 in the fields of Saga near Kyoto to catch insects. Everybody from the head priest downward gathered horses from official pavilions and departed the capital with stylized bamboo cages with dangling decorative cords. The party dismounted at Toyomachi and proceeded on foot. They caught insects until evening and then returned to the capital, where they fed the crickets and other creeping creatures leaves from bush clover and a perennial plant with yellow flowers (*Patrinia scabiosaefolia*). Once back in the palace, the courtiers raised their saké cups and composed poetry regarding the occasion.[51] The fictional Prince Genji had autumn insects released into his garden in order to create a lonely mood that evoked, as Heian courtiers were want to do, a Buddhist sense of impermanence and, as we have seen, transcendence.[52]

Later, in the eighteenth and early nineteenth centuries, the admirers of insect songs learned how to cultivate crickets in how-to books. Raising the eggs of the pine cricket (*Xenogryllus marmorata*) proved relatively simple and something that any enthusiast could do.[53] The ability to cultivate insects led to the business of insect vendors (*mushi uri*) in some towns and cities. In the nineteenth century as well, Kitagawa Morisada described the practice of selling insects as one of the "modern customs" of Tokugawa Japan. On city streets, decorative bamboo cages dangling from colorful insect-vendor kiosks contained singing bell crickets (*Homoeogryllus japonicus*), giant katydids (*Mecopoda elongata*), pine crickets (*Xenogryllus marmorata*), buprestid beetles (*Chrysochroa fulgidissima*), and many others.[54]

So, historically speaking, Japanese kids and their parents knew something about collecting and keeping bugs, because it was part of Japan's cultural heritage. U.S. entomologists tapped into this historical expertise to collect and deploy their biotechnologies. By 1924, after releasing beetles with eggs around their thoraxes, entomologists spotted parasitized Japanese beetles within a twelve-mile radius of Riverton.[55] The policy decision was a success: the fate of the Japanese beetle in the United States was sealed, but chemical companies and their political allies still pushed hard for the use of chemical insecticides, both in the United States and abroad.

The Age of Chemical Insecticides

Chlorinated hydrocarbons and organophosphates caught on in Japan after the Pacific War. Whale oil was an insecticidal technology gained from boiling the blubber of whales; deploying tachinid flies, by contrast, was entirely an issue of overcoming island biogeographies and transporting the predatory insects to the United States. Postwar insecticides proved altogether different in the manner that they interacted with insect bodies and the environment, and these chemicals provide our final case study.

The utterly lethal organophosphorus ester insecticide "parathion" ranked among the most deadly poisons in the world and among the favorites of Japan's postwar farmers, pesticide companies, and, somewhat surprisingly, people who sought to commit suicide or even homicide.[56] As Linda Nash has shown, it was a favorite among the fruit growers of California as well. As early as 1949, California farmers applied parathion to their fields and orchards; that same year, in Marysville, California, twenty-five migrant workers became seriously ill after entering an orchard prayed previously with parathion. Nash has stressed nature's unanticipated agency when it comes to the toxicity and human-health threat represented by such chemicals. Nash writes, "A study of parathion decay conducted in the 1970s revealed that pesticide residues in the same fields could vary as much as 90-fold, depending upon the time of year the chemical was applied." In other words, "Once introduced into the environment, OP (organophosphate) chemicals were subject to the uncontrolled agency of nature."[57] Of course, this is precisely the nature of the unanticipated, unforeseen "eco-system" accidents described by Perrow at the outset of this article.

In Japan, parathion injured people and environments in a similar fashion, but it also did so according to unanticipated, social system (as opposed to just eco-system) accidents. That a government warning of the dangers of parathion's extreme toxicity served to alert those who wanted to commit suicide of its effectiveness is a wonderful—if incredibly grim—example of the unanticipated manner in which policy decisions and information crosscut different social networks to say different things and have different consequences to different people. Ironically, but not surprisingly, the numerous suicides resulting from consuming parathion and its relative biocide paraquat are systematically related to government and corporate efforts to stem accidental exposure to the insecticide through the dissemination of information regarding its toxic qualities.

The German chemist Gerhard Schrader developed the first organophosphate chemicals at the Farbenfabriken Bayer AG facilities in 1937 and the Nazis merrily continued their development as a chemical weapon. Although several generations removed, parathion is related to sarin gas, which the Japanese cult Aum Shinrikyo, led by its spiritual leader Asahara Shoko, used to murder twelve and injure thousands of Tokyo subway riders in March 1995. Chemists developed parathion in 1944 and it began replacing DDT in the 1950s, mainly because of its suitability as an insecticide: it persisted well in the environment and did not break down in sunlight or water.[58] Obviously, these same resilient qualities made it a dangerous environmental polluter—it haunts environments for ages, not to mention that it morphs into even deadlier forms under nature's unanticipated auspices.

When Japanese farmers began spraying parathion on their rice crops in the 1950s, they noticed quick results and yields soared. One doctor overoptimistically boasted that, as a result of parathion, Japan's perennial postwar food shortage had been "solved." But better yields came at a high cost: in a period of six years, between 1953 and 1958, physicians reported nearly ten thousand instances of parathion poisoning and three thousand of those proved fatal.[59] Basically, parathion, as with all organophosphates, is a cholinesterase inhibiter and so, in larger doses, it can kill and, in smaller doses, it can injure reproduction; the symptoms include muscle twitching (fasciculation), breathing difficulties, profuse sweating, and urinary and fecal problems.[60] It should not be surprising, then, that early on some Japanese researchers suspected parathion as being responsible for fetal deaths and other difficulties. In the 1950s, the Japanese government distributed some fifty thousand grams of moderately successful "oxime" therapy around the country to treat potential cases of parathion poisoning. With one treatment requiring between one and two grams per patient, the Japanese government, we can assume, anticipated tens of thousands of cases of accidental poisoning.[61]

Originally, farmers used parathion to kill rice-eating bugs, such as Asiatic rice borers (*Chilo suppressalis*), stinkbugs (*Pentatomidae*), and plant hoppers, but policymakers also targeted fruit and vegetables eaters, such as aphides and leaf folders. The Japanese imported parathion from Bayer and American Cyanamid in the form of an emulsion (a liquid that is a mixture of one or more liquids) in 1951. Quickly, the Ministry of Agriculture and Forestry hailed the effectiveness of the chemical against the Asiatic rice borer and appropriated 40 million yen for experiments in mass extermination. But because parathion is extremely poisonous, two high-profile incidents alerted people to its dangers: a girl from Shizuoka prefecture and an agricultural reform advocate from Hyogo prefecture died from parathion poisoning.[62] In response, lawmakers passed ordinances to alert people to parathion's toxicity.

Originally, the government passed the Agricultural Chemical Control Law (*Noyaku torishimari no hosei*) in 1948 less to prohibit the circulation of illegal, highly toxic, or poor-quality chemicals than simply to increase production and improve their quality. As Gerald Markowitz and David Rosner document in the United States, big chemical companies, not victims of chemical poisons, had the undivided attention of policymakers and the same was true in Japan.[63] But the government voiced good intentions and its statement is worth quoting, because of the similarities to the case of the United States. According to the Japanese government: "This law establishes a registry system for agricultural chemicals and, more than act to control their sale and use, to promote safety it normalizes the quality of agricultural chemicals and ensures proper use of them. It also stabilizes the production of agricultural chemicals and contributes to the protection of the health of the citizenry, together with contributing to the preservation of the living environment of the citizenry."[64] Ultimately, the law would be revised on three occasions (1951, 1962, and 1963); and it was not until October 1972 that it was given any real teeth by what is called the "Pollution Diet." Five years after the original law, the Welfare and Agriculture and Forestry ministries started enacting tougher "control laws" to educate people about the dangers of agricultural products, particularly parathion and methyl parathion. In August 1955 the government listed parathion as a "special poison" (*tokutei dokubutsu*), one year after Sumitomo Chemical began its domestic manufacture.[65]

Unabashedly, Sumitomo's corporate histories published as late as the 1980s gush that the development of parathion provided a "valuable service" to "our country." According to these histories, Sumitomo discovered the economic promise of parathion in July 1950 after the company president, Doi Masaharu, visited the headquarters of American Cyanamid. In September of the next year, American Cyanamid sought to establish international economic ties to Japan and tapped Sumitomo to peddle the chemical in East Asia more broadly. Initially, the strategy was that American Cyanamid would offer Sumitomo parathion to sell in Asia and, over time, nurture a robust market for the insecticide. Then, once market share had been created, Sumitomo would be taught how to manufacture the chemical itself. In June 1951, at about the same time that American Cyanamid tried to expand the parathion market in East Asia, Bayer began marketing "Folidol"—their proprietary name for parathion—in Japan as well. Subsequent tests in agricultural experiment stations proved that the chemical killed Asiatic rice borers in rice paddies, dry-land crops, and fruit orchards. Not surprisingly, policymakers quickly approved Folidol for use in Japan. Its toxic effectiveness was a far cry from the whale-oil insecticides of the Kyoho famine, but so was the effectiveness of the institutional systems through which it disseminated from chemical corporations to agricultural lands to human bodies.

Meanwhile, the Sumitomo relationship with American Cyanamid continued to solidify. In March 1952, Sumitomo became American Cyanamid's "Japan delegate" for the marketing and manufacture of parathion; later, in September of that same year, the two companies jointly decided that Sumitomo would construct factories in Japan to manufacture parathion but that, until that time, Sumitomo would import and sell the American product. By November 1953, Sumitomo was importing and selling American Cyanamid's product. Importantly, there was a slight difference between the parathion produced by American Cyanamid and Bayer: the former manufactured ethyl parathion, while the latter produced methyl parathion. Comparatively speaking, ethyl parathion is more toxic, though both, if handled improperly (or even properly), can prove deadly.[66] To Sumitomo, the Bayer product appeared more appropriate to Japan's small farms and so the company sought a licensing agreement with Bayer; but immediate postwar economic conditions in Japan prompted the government to try to limit the number of imports and begin more domestic production and this extended to the chemical industry as well. With the government urging Sumitomo to begin the immediate domestic production of parathion, the Japanese company acquired licenses to manufacture

American Cyanamid's product in May 1953 and Bayer's product a bit later, in October 1953.

Production began at Sumitomo's Tsurusaki plant. The site proved optimal for two reasons: the company already stored the raw material paranitrochloro benzene (PNCB) at the site, and facilities at the site that had once produced monochloro benzene (but had been idle since 1951) could be put back to use for the company. By March 1954, at the Tsurusaki plant, Sumitomo began the monthly production of some thirty tons of ethyl parathion. To boost production still, Sumitomo's Okayama Plant, which produced monochloro benzene, an ingredient in ethyl parathion, was fully automated for remote operation. By March 1955, Sumitomo had begun the production of Bayer's methyl parathion at the Tsurusaki site was well. That year, Sumitomo manufactured some fifty tons of ethyl and methyl parathion at the Tsurusaki plant.

In April 1955, Sumitomo manufactured enough parathion to halt importing the chemical from the United States and, in time, it supplied all Japanese domestic consumption of the pesticide. Manufacture of the insecticide expanded at a staggering pace: in 1955, the Tsurusaki plant boasted a monthly production of 630 tons; by 1960 that number had increased to 1,000 tons. Starting in September 1957, Sumitomo marketed parathion throughout Japan under the Bayer name Folidol. Simultaneously, Sumitomo established the Parathion Research Group (Parachion Kenkyukai) in 1954 and, presumably in response to the highly toxic nature of the insecticide, the Parathion Poisoning Remedy Research Group (Parachion Chudoku Chiryoho Kenkyukai) in 1955.[67] Parathion became nothing less than a ubiquitous part of Japan's chemical industry and agrarian landscapes, from dry-land crops and orchards to terraced paddies. But once in the fields, eco-system accidents and social system accidents began to occur in a manner that few advocates or critics of the chemical could have anticipated.

To be sure, hundreds of people died as a result of accidental poisonings. But in a ghoulish twist, in Japan policy decisions to warn people of accidental poisoning by parathion proved to be part of the public-health threat posed by the insecticide. In 1956, one year after policymakers designated parathion as a "special toxin," accidental death rates plummeted from eighty-six people to twenty-nine. That same year, however, the use of parathion for suicides or as a murder weapon nearly doubled. Obviously, the designation "special toxin" possessed two voices that emerged when it crosscut different social networks: it served to warn some and advertise to others.

The use of parathion and related agricultural chemicals for suicide is striking. Japan remains a country that stresses social conformity that has, according to some specialists, contributed to its dubious distinction of having one of the highest suicide rates in the industrialized world. In the 1950s, the ingestion of large doses of parathion was one method of choice for those hoping to end their lives. By the 1980s, however, the herbicide known as paraquat had become the poison of choice. Chemists developed paraquat in 1882, but its propensity to kill pests was not discovered until 1959. This bipyridyl herbicide ranks among the most deadly pulmonary poisons known and so has attracted an enormous amount of scientific attention.[68] Basically, paraquat releases oxygen-fee radicals that painfully destroy lung and kidney tissue. In Japan, the number of suicidal, homicidal, and accidental deaths from paraquat increased steadily in the mid-1980s: from 594 in 1984 to 1,021 in 1985. Of the 1,021 deaths reported in 1985, over 96 percent of those proved suicidal. What made young people contemplating suicide aware of its lethal properties was a series of indiscriminate, and highly sensationalized, soft-drink poisonings that left seventeen dead in 1985; another reason was that, in the 1980s, paraquat was readily available in Japanese garden shops and unwittingly advertised as a "special toxin" by the Japanese government. Today, the Japanese government has severely restricted the chemical to only those people with proper documentation and laced the herbicide with vivid colors and rancid odors to make it less palatable to those who might drink it.[69]

Conclusion

As early as March 1966, Japan's Diet began taking steps against certain toxic insecticides, such as phenyl-mercury; even earlier, the Ministry of Agriculture and Forestry, in both May 1965 and May 1966, had directed that nonmercuric pesticides replace mercuric ones.[70] By December 1969, the government suspended the production of parathion and TEPP; by the summer of that same year, even the sale of ethyl and methyl parathion had been prohibited. Sumitomo histories explain that the suspension of parathion production was caused by two factors: pesky insects such as the Asiatic rice borer had developed evolutionary resistances to the chemical, and it killed or poisoned too many people. But between 1954 and 1969, for a period of sixteen years, 6,648 tons of ethyl parathion and 3,960 tons of methyl parathion—a total of 10,608 tons sprayed throughout Japan—had been manufactured and sold in Japan.[71] Soon thereafter, in May

1971, the government prohibited the sale of DDT, while sales of BHC, endrin, dieldrin, and aldrin were restricted. One month later, the government prohibited the use of parathion, methyl parathion, and TEPP.[72] In 1972, the government passed a series of laws prohibiting or seriously restricting many highly toxic agricultural chemicals.

What these six case studies tell us about the interrelationships among government and corporate policy decisions, social networks, cultural sensibilities, toxic chemicals, and Japan's ecosystems is that policy history needs to be placed in broader contexts. When it comes to chlorinated hydrocarbons or organophosphates, derelict policy decisions are not just derelict policy decisions; they are decisions that resonate throughout the natural and unnatural systems in which human populations remain deeply imbedded. Policy decisions, when amplified through hybridized systems, cause evolution in the form of hereditary resistances among resilient insect populations, unanticipated ecosystem accidents in highly engineered agricultural landscapes, epidemic disease as a result of anthropogenic biogeographic proximity (i.e., proximity among pigs, humans, and mosquitoes), and health problems among human consumers who, when at the dinner table, interface directly with all these "trophic" (food-chain) layers.

That is, not all evolution is a result of chance. The policy decisions humans conjure—whether economically driven to cull certain silkworms or designed to situate piggeries near cities and their cemeteries for access to garbage, or religiously driven to combat pesky insects through spells, or scientifically driven to manufacture more lethal biocides—are broadcast through natural systems and directly affect human and nonhuman health.

Montana State University,
Bozeman

Notes

1 This subfield of environmental history is often called "envirotech." As the name suggests, it bridges scholarship in the history of technology and environmental history. See Timothy LeCain, "What Is Envirotech? Some Emergent Properties of a New Historical Subfield," *The Envirotech Newsletter* 5 (2005): 1, 4–5.

2. The intriguing argument that human enterprises, such as industry, science, and technology, have so transformed nature that the planet no longer exists in its previously recognizable form, whatever that might have been for people, is articulated nicely in Bill McKibben, *The End of Nature* (New York, 1997).

3. See chapter one of my *The Lost Wolves of Japan*, foreword by William Cronon (Seattle, 2005). In many respects, the morphological development of the Japanese wolf, *C.l. hodophilax*, and hence its taxonomic designation, was the product of anthropogenic environmental forces in Japan's early modern and modern histories.

4. Edmund Russell, "Evolutionary History: Prospectus for a New Field," *Environmental History* 8 (April 2003): 205–6.

5. On the "big chicken" industry in the United States, see Steve Striffler, *Chicken: The Dangerous Transformation of America's Favorite Food* (New Haven, 2005).

6. Michael Pollan has discussed the theme of "co-evolution" in relationship to certain desirable plants in *The Botany of Desire: A Plant's-Eye View of the World* (New York, 2002).

7. Edmund Russell, "Introduction: The Garden in the Machine: Toward an Evolutionary History of Technology," in *Industrializing Organisms: Introducing Evolutionary History,* ed. Susan R. Schrepfer and Philip Scranton, Hagley Perspectives on Business and Culture, vol. 5 (New York, 2004), 1, 4, 8, 11, 13.

8. Pete Daniel, *Toxic Drift: Pesticides and Health in the Post-World War II South* (Baton Rouge, 2005).

9. Joshua Blu Buhs, *The Fire Ant Wars: Nature, Science, and Public Policy in Twentieth-Century America* (Chicago, 2004).

10. Jonathan Weiner explores some insect resistances in *The Beak of the Finch* (New York, 1994), 253–55.

11. Deborah Kay Fitzgerald, *Every Farm a Factory: The Industrial Ideal in American Agriculture* (New Haven, 2003).

12. For an excellent treatment of forms of biomagnification, see Sandra Steingraber, *Having Faith: An Ecologist's Journey to Motherhood* (Cambridge, 2001).

13. Charles Perrow, *Normal Accidents: Living with High-Risk Technologies* (New York, 1984; repr., Princeton, 1999), 14, 233, 295, 296.

14. On social networks, see John F. Padgett and Christopher K. Ansell, "Robust Action and the Rise of the Medici, 1400–1434," *American Journal of Sociology* 98, no. 6 (May 1993): 1259–65. As for ecosystems, the British plant ecologist Arthur Tansley coined the term "ecosystem" in 1935. He wrote that "the whole *system* (in the sense of physics) including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome—the habitat factors in the widest sense." See Robert P. McIntosh, *The Background of Ecology: Concepts and Theory* (Cambridge, 1985), 193.

15. Marian R. Goldsmith, Toru Shimada, and Hiroaki Abe, "The Genetics and Genomics of the Silkworm, Bombyx mori," *Annual Review of Entomology* 50 (January 2005): 71–100.

16. A standard treatment of Heian Japanese aesthetics and cultural sensibilities is Ivan Morris, *The World of the Shining Prince: Court Life in Ancient Japan* (New York, 1964).

17. Goldsmith, Shimada, and Abe, "The Genetics and Genomics of the Silkworm," 71–100.

18. Kasai Masaaki, *Mushi to Nihon bunka* (Insects and Japanese culture) (Tokyo, 1997), 72–73.

19. *Kojiki* (Record of Ancient Matters), translated with an introduction and notes by Donald L. Philippi (Tokyo, 1968), 87.

20. Ibid., 313.

21. Brett L. Walker, "Commercial Growth and Environmental Change in Early Modern Japan: Hachinohe's Wild Boar Famine of 1749," *Journal of Asian Studies* 60, no. 2 (Spring 2001): 329–51.

22. Simon Partner, *Toshié: A Story of Village Life in Twentieth-Century Japan* (Berkeley and Los Angeles, 2004), 17–20.

23. An excellent treatment of early modern Japanese rural lending institutions is Ronald P. Toby, "Both a Borrower and a Lender Be: From Village Moneylender to Rural Banker in the Tempô Era," *Monumenta Nipponica* 46, no. 4 (Winter 1991): 483–512. In the context of Japan's "household system," it fell on the shoulders of peasant women such as Matsuo Taseko to care for silkworms and thereby elevate the wealth of their husbands' households. See Anne Walthall, *The Weak Body of a Useless Woman: Matsuo Taseko and the Meiji Restoration* (Chicago, 1998).

24. For example, Lady Nijo lamented the death of her lover, the emperor, with a poem that referred to the seasonal (and hence representative of transient) calls of insects and deer. See *The Confessions of Lady Nijo,* trans. Karen Brazell (Stanford, 1973).

25. David B. Lurie, "Orientomology: The Insect Literature of Lafcadio Hearn (1850–1904)," in *JAPANimals: History and Culture in Japan's Animal Life,* ed. Gregory M. Pflugfelder and Brett L. Walker (Ann Arbor, 2005), 245–62.

26. Lafcadio Hearn, *Kwaidan: Stories and Studies of Strange Things* (Boston, 1904; repr., Rutland, Vt., 1971), 184, 207–12.

27. In 1900, Japanese built 1,396 slaughterhouses throughout their country. At these slaughterhouses, between 1893 and 1902, employees dispatched over 1.7 million cattle to fuel the workers and soldiers of modern Japan. Pigs were an important industrialized organism as well. See The Department of Agriculture and Commerce, ed. *Japan in the Beginning of the 20th Century* (Tokyo, 1904), 184–200.

28. "The Livestock Industry of Japan," Report Number 30, General Headquarters, Supreme Commander for the Allied Powers, Natural Resources Section, APO 500, 18 April 1944.

29. John W. Dower, *Embracing Defeat: Japan in the Wake of World War II* (New York, 1999), 133.

30. Daniel Barenblatt, *A Plague upon Humanity: The Hidden History of Japan's Biological Warfare Program* (New York, 2004), 9–10.

31. "Japanese Use the Chinese as 'Guinea Pigs' to Test Germ Warfare," *Rocky Mountain Medical Journal* 39, no. 8 (August 1942): 571–72; *Materials on the Trial of Former Servicemen of the Japanese Army Charged with Manufacturing and Employing Bacteriological Weapons* (Moscow, 1950); John W. Powell, "A Hidden Chapter in History," *The Bulletin of the Atomic Scientists* 37, no. 8 (October 1981): 49–50.

32. Edmund P. Russell, "'Speaking of Annihilation': Mobilization for War Against Human and Insect Enemies, 1914–1945," *Journal of American History* 82, no. 4 (March 1996): 1505–6, 1508, 1511, 1522–27. On the dehumanization of the enemy, both in the United States and Japan, see John W. Dower, *War Without Mercy: Race and Power in the Pacific War* (New York, 1986).

33. Buddhist beliefs provide one reason why Japanese cultivators believed that talismans from shrines such as Mt. Zozu's Konpira, on Shikoku Island, prevented serious insect damage. See Sarah Thal, *Rearranging the Landscape of the Gods: The Politics of a Pilgrimage Site in Japan, 1573–1912* (Chicago, 2005), 106–7.

34. J. H. Mun, Y. H. Song, K. L. Heong, and G. K. Roderick, "Genetic Variation among Asian Populations of Rice Planthoppers, *Nilaparvata lugens* and *Sogatella furcifera* (Hemiptera: Delphacidae): Mitochondrial DNA Sequences," *Bulletin of Entomological Research* 89 (1999): 245–53.

35. In what is called the *kokudaka* system, the Tokugawa regime measured the wealth of feudal domains and their retainers according to an amount called *koku,* wherein one *koku* equaled 5.1 bushels of rice. The philosophy behind this amount was that one *koku* of rice could feed a human for one year.

36. *The Ten Foot Square Hut and Tales of the Heike,* trans. A. L. Sadler (Sydney, 1928), 123–24.

37. Robert Borgen, *Suguwara no Michizane and the Early Heian Court* (Honolulu, 1986), 278–325.

38. For more on whaling in Japan, see Arne Kalland and Brian Moeran, *Japanese Whaling: End of an Era?* (London, 1992). See also Arne Kalland, *Fishing Villages in Tokugawa Japan* (Honolulu, 1995).

39. Kikuchi Isao, *Kinsei no kikin* (Early modern Japan's famines) (Tokyo, 1997), 82–89.

40. Conrad Totman, *Early Modern Japan* (Berkeley and Los Angeles, 1993), 236–38.

41. Once again, these two terms refer to Japanese imperial reign names. The Tenmei period lasted from 1781 to 1788; the Tenpo period lasted from 1830 to 1843.

42. The need to get more productivity out of rural lands with fewer laborers also led to the development of nitrogenous fertilizers. See Barbara Molony, *Technology and Investment: The Prewar Japanese Chemical Industry* (Cambridge, Mass., 1990), 17–266. For more recent data on fertilizer use, see David Vogel, "Consumer Protection and Protectionism in Japan," *Journal of Japanese Studies* 18, no. 1 (Winter 1992): 131–32.

43. The Meiji Japanese adoption and adaptation of Euro-American science is covered in James R. Bartholomew, *The Formation of Science in Japan* (New Haven, 1989).

44. On the role of foreign experts in refashioning Hokkaido and agricultural practices there, see Hokkaido Prefectural Government, ed. *Foreign Pioneers: A Short History of the Contribution of Foreigners to the Development of Hokkaido* (Sapporo, 1968). See also Fumiko Fujita, *American Pioneers and the Japanese Frontier: American Experts in Nineteenth-Century Japan* (Westport, Conn., 1994); John M. Maki, *William Smith Clark: A Yankee in Hokkaido* (Sapporo, 1996).

45. James Whorton, *Before Silent Spring: Pesticides and Public Health in Pre-DDT America* (Princeton, 1974), 8–9, 12, 15–16, 20, 22, 64–65.

46. Matsunaka Shoichi, *Nihon ni okeru noyaku no rekishi* (Japan's agricultural chemical history) (Tokyo, 2002), 9–11. For more specific information on plant disease, insects, and insecticides from the Meiji period through the 1950s, see Tennensha Jiten Henshubu, ed. *Byochu noyaku jiten* (Dictionary of agricultural chemicals for disease and insects) (Tokyo, 1955).

47. Historian Irokawa Daikichi famously discovered a draft, nineteenth-century constitution, written by commoners, tucked in the attic of a rural farmhouse. The writings of Jefferson and Rousseau inspired much of the unofficial document. See Daikichi Irokawa, *The Culture of the Meiji Period,* trans. Marius Jansen (Princeton, 1988). Nonetheless, Ito Hirobumi and his advisers, when drafting the official Meiji Constitution of 1889, relied mostly on Prussian monarchical theories. See Carol Gluck, *Japan's Modern Myths: Ideology in the Late Meiji Period* (Princeton, 1985).

48. Charles S. Elton, *The Ecology of Invasions by Animals and Plants* (London, 1958; repr., Chicago, 2000), 52–54.

49. Aldrin and dieldrin are closely related chemicals that fall under the cyclodiene classification of chlorinated hydrocarbons. Once sprayed in the environment, both chemicals bioconcentrate and biomagnify in a manner that kills or inhibits the reproductive success of many nonhuman species, especially in avian species.

50. David Quammen, *Monster of God: The Man-eating Predator in the Jungles of History and the Mind* (New York, 2003), 426–27.

51. Tachibana Narisue, *Kokon chomonju* (Notable tales old and new), vol. 2, in *Shincho Nihon koten shusei* (Shincho collection of classical Japanese literature), vol. 76, ed. Nishio Koichi and Kobayashi Yasuharu (Tokyo, 1986), 372. For a description of this collection, see Yoshiko K. Dykstra, "Notable Tales Old and New: Tachibana Narisue's *Kokon Chomonju,*" *Monumenta Nipponica* 47, no. 4 (Winter 1992): 469–93.

52. Murasaki Shikibu, *The Tale of Genji,* trans. and with intro. by Edward G. Seidensticker (New York, 1997), 671.

53. *Churyo manroku,* cited in Kasai, *Mushi to Nihon bunka,* 132–33.

54. Kitagawa Morisada, *Ruiju kinsei fuzokushi* (Record of various modern customs), ed. Muromatsu Iwao (Tokyo, 1928), 167.

55. Curtis P. Clausen, J. L. King, and Cho Teranishi, "The Parasites of *Popillia Japonica* in Japan and Chosen (Korea), and Their Introduction into the United States," *United States Department of Agriculture Department Bulletin* 1429 (January 1927): 1–55.

56. See, for example, Watanabe Yuji, *Kurashi ni hisomu kagaku dokubutsu jiten* (A Dictionary of chemical poisons that lurk in our daily lives) (Tokyo, 2002), 74; Nakaminami Gen, *Noyaku genron* (The principles of agricultural chemicals) (Tokyo, 2001), 23–25; Miura Yoshiaki, *Kagaku osen to ningen no rekishi* (Chemical contamination and human history) (Tokyo, 1999), 73–74; Yasuhara Akio, *Shinobi yoru kagaku busshitsu osen: Chikyu tanjo, seitaikei, gendai bunmei ni okeru kagaku busshitsu osen no keifu* (Exposing chemical contamination: The birth of earth, ecological structure, and the genealogy of chemical contamination in the

context of modern civilizatation) (Tokyo, 1999), 143–45; Ando Mitsuru, *Yokuwakaru noyaku osen: Jintai to kankyo o mushibamu gosei kagaku busshitsu* (Agricultural chemical contamination: The synthetic chemical compounds that ruin human bodies and the environment) (Tokyo, 1990), 21–25.

57. Linda Nash, "The Fruits of Ill-Health: Pesticides and Workers' Bodies in Post–World War II California," *Osiris* 19 (2004): 205, 208. See also Linda Nash, "Finishing Nature: Harmonizing Bodies and Environments in Late-Nineteenth-Century California," *Environmental History* 8 (January 2003): 25–52.

58. Curtis D. Klaassen, ed. *Casarett & Doull's Toxicology: The Basic Science of Poisons,* 5th ed. (New York, 1996), 655.

59. Tatsuji Namba, "Oxime Therapy for Poisoning by Alkylphosphate-Insecticides," *Proceedings of the 13th Annual International Congress on Occupational Health, July 25–29, 1960* (1961): 757.

60. Takashi Tanimura, "Embryotoxicity of Acute Exposure to Methyl Parathion in Rats and Mice," *Archives of Environmental Health* 15 (November 1967): 609–13.

61. Namba, "Oxime Therapy for Poisoning by Alkylphosphate-Insecticides," 757–58.

62. Uemura Shinsaku, Kawamura Hiroshi, Tsuji Machiko, Tomita Shigeyuki, and Maeda Shizuo, *Noyaku dokusei no jiten* (Dictionary of toxic agricultural chemicals) (Tokyo, 2002), 146–47.

63. Gerald Markowitz and David Rosner, *Deceit and Denial: The Deadly Politics of Industrial Pollution* (Berkeley and Los Angeles, 2002).

64. Kankyo Horei Kenkyukai, ed. *Kankyo kogai nenkan* (Yearbook of environmental public damage) (Tokyo, 1973), 137.

65. Shimokawa Koshi, ed. *Kankyoshi nenpyo: Showa-Heisei hen* (Environmental history chronology: Showa and Heisei periods), vol. 2 (Tokyo, 2004), 193.

66. For some examples of the deadly consequences of parathion use, see Daniel, *Toxic Drift,* 108–24.

67. Sumitomo Kagaku Kogyo Kabushikigaisha, ed. *Sumitomo Kagaku Kogyo Kabushikigaisha shi* (A history of Sumitomo Chemical) (Osaka, 1981), 305–9.

68. Klaassen, ed., *Casarett & Doull's Toxicology,* 673.

69. Yoshimoto Takahashi, Hideto Hirasawa, and Keiko Koyama, "Restriction of Suicide Methods: A Japanese Perspective," *Archives of Suicide Research* 4 (1998): 103–4.

70. The fixation with mercury was in part due to the outbreak of "Minamata disease," or methyl-mercury poisoning, in southern Japan. See Norie Huddle and Michael Reich with Nahum Stiskin, *Island of Dreams: Environmental Crisis in Japan,* foreword by Dr. Paul R. Ehrlich and afterword by Ralph Nader (New York, 1975), 102–32; Frank K. Upham, *Law and Social Change in Postwar Japan* (Cambridge, Mass., 1989), 28–77; Jun Ui, *Industrial Pollution in Japan* (Tokyo, 1992), 103–32; and Timothy S. George, *Minamata: Pollution and the Struggle for Democracy in Postwar Japan* (Cambridge, Mass., 2001). On the pathology of "Minamata disease," see Masazumi Harada with Aileen M. Smith, "Minamata Disease: A Medical Report," in W. Eugene Smith and Aileen M. Smith, *Minamata* (New York, 1975), 180–92; Tadao Tsubaki and Katsuro Irukayama, ed. *Minamata Disease: Methylmercury Poisoning in Minamata and Niigata, Japan* (Tokyo and Amsterdam, 1977); Tadao Takeuchi and Komyo Eto, *The Pathology of Minamata Disease: A Tragic Story of Water Pollution* (Fukuoka, 1999).

71. Sumitomo Kagaku Kogyo Kabushikigaisha, ed. *Sumitomo Kagaku Kogyo Kabushikigaisha shi,* 543–44.

72. Shimokawa, ed. *Kankyoshi nenpyo: Showa-Heisei hen,* 283.